Liquefaction of sands and its effects on buried structures

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1. Background

In regions of high seismic activity, soil liquefaction has been identified as a major hazard to buried structures. Liquefaction has been defined as the transformation of cohesion less material from a solid state into a liquefied state as a consequence of increased pore pressure and reduced effective stress. Liquefaction of a soil deposit does not necessarily mean that ground failure occurs, but when liquefaction is combined with certain geologic conditions, it can lead to large permanent ground movement and soil failure. Conditions most conducive to liquefaction involve loose cohesion less granular deposits combined with a high water table. Lateral spreading and settlement are one of the most common forms of ground deformation associated with liquefaction during earthquakes. Lateral spreading and settlement pose special problems for buried constructions in areas subject to earthquakes. For the siting and design of underground constructions like piles and pipelines in seismic regions, it is important to identify areas susceptible to liquefaction. Over the years, some of the most substantial, and costly damages to the early slopes and the foundation of structures has been due to liquefaction of sands during earthquakes; hence, it is imperative to take countermeasures against liquefaction and suggest an approach to combat it such that while the soil liquefies, the damage is minimum.

2. Aims

The aim of this project is to:

a) To examine the influence of various factors on the liquefaction susceptibility of sandy sites and the magnitude of associated ground deformations (settlement, lateral spreading);

b) To investigate the effect of the liquefaction on buried structures (piles, pipelines); and

c) To assess the effectiveness of various countermeasure techniques.

3. Research Methodology

This project will be carried out in two stages so as to ensure achieving reliable and accurate results. The main focus of this project will be on Ottawa and Nevada sand as these kinds of sands are so popular in this topic. Moreover, a majority of scientists have done their research on this sand in liquefaction topic and it can give me more chance to validate the results of project with other works. In the first stage, a table model for the seismic laboratory will be constructed and tests will be run. In the second stage, upon completion of testing, the settlement of liquefaction, lateral spreading, pure water pressure and the effect of the geometry of the pipe on the capacity of the different layers of soil liquefaction potential will be evaluated through displacement. After analysing the experimental results, the laboratory model will be modelled through numerical simulation with FALC program and the model will be appraised based on input parameters. Finally, the numerical model will be estimated by comparing the experimental and numerical model. Then, diverse elements including the settlement of liquefaction, lateral spreading, pure water pressure and effect of the geometry of the pipe on the capacity of the different layers of soil liquefaction potential will be evaluated based on changing parameters by means of software numerical. In addition, there are other factors that can be assessed during testing experimental model.
Parameters include:
The effect of loading frequency; the effect of underground constructions materials; the effect of the thickness of underground structures; the effect of soil dilation angle; the effect of thick layer of liquefaction; the effect of diameter pipe; the effect of buried deep underground structures; the effect of damping soil; the effect of the relative density of soil; the effect of underground water level

4. Significance

Small-scale modelling of a full-scale prototype offers advantages in that the model may be constructed more easily, thus saving time and money, and the model test may be conducted in a controlled environment.

Demystifying the behavior of granular media by a micromechanics-based plasticity model

Granular materials are ubiquitous and important to our everyday life. They are seen in form of both natural and engineering materials, such as sand, sugar, food grains and powders in agricultural, pharmaceutical, energy and chemical industries. Indeed, granular materials are the second-most manipulated material in the industry (next to water). As a typical example of granular media, sand is important to a wide range of key infrastructures pertaining to the quality and safety of our daily life and the economy of many countries around the world. Many new infrastructures such as wind turbines, high-speed railways, tunnels, pipelines and earth dams which are lifelines to the economy of many countries will be unavoidably built on/in sand. The mechanical behavior of sand underpins the critical performance and serviceability of these structures and is the key factor to be considered in their design, construction, operation and maintenance. Due to the geological deposition process, most sands exhibit highly anisotropic fabric structures which are closely associated with preferentially orientated particles, void spaces and interparticle contacts. Fabric anisotropy has profound effect on the mechanical behavior of sand and thus influences such phenomena as embankment failure and soil liquefaction (the contact forces between sand particles are so low that the sand behaves like liquid) which can cause catastrophic hazards to both human lives and properties. If the soil is assumed isotropic, the associated geotechnical design will be either too dangerous or too conservative. For instance, back-analysis indicated that liquefaction failure of the Lower San Fernando Dam in 1971 has been due to neglecting of the fabric effect on sand liquefaction resistance in design.

This project aims to develop a micromechanics-based plasticity model for sand accounting for effect of sand anisotropy and its evolution.

Robust, efficient and accurate numerical technique will be developed to implement the proposed model in the finite element software package Abaqus which is widely used in geotechnical design and research. The model will then be used to do improved analysis of some challenging geotechnical problems through collaboration with industry. Engineering protocol for considering soil anisotropy in geotechnical design will then be developed based on the numerical analysis and its application in real geotechnical problems.

Liquefaction failure in intermediate soil

1. Background

Towhata defined liquefaction as the point at which the pressure of pore water increases to a level that is nearly equal to the total confining initial stress. This implies that the effective stress must be zero and equal to the pressure of the pore water. Artiola et al. defined intermediate soil as having properties that vary from clay to sand. The properties of intermediate soil such as sandy clay, clayey sand, and low plasticity silt clay make it difficult to determine the appropriate engineering procedures required to estimate the liquefaction potential. There is poor understanding of the effects and behaviour of sampling disturbance on intermediate soil. There are difficulties in identifying whether or not correlation-based in situ laboratory tests are best for determining the potential liquefaction of field samples. The present project will examine liquefaction in intermediate soil to show that liquefaction has an effect worth considering on engineering construction for both short- and long-term structures. This subject has gained attention because if its relevance to construction.

2. Aim

Liquefaction in intermediate soil will be observed through empirical evidence gathered in laboratory testing through monotonic cyclic consolidation and post-cyclic behaviour. The project investigates the vulnerability of intermediate soil and the effects of disturbance on the soil. The results of the laboratory procedures and the findings were then related to ground failure associated with liquefaction. The limitations found will be explored based on the conceptions derived from in situ and laboratory data. The project seeks to correct the limitations and provide an understanding of the essential behaviour of low-plasticity fine-grained and intermediate soil and find the most appropriate engineering procedure for evaluating the liquefaction potential of intermediate and fine-grained soils. The goal is to correct limitations on the current in situ and laboratory data.

An example of the flaw that can be corrected is that which occurs during calculation of the liquefaction potential index (PL) by multiplying the danger function and weight depth function. The expected result should reflect liquefaction potential as calculated for the interval of depth. This is sometimes erroneous, hence, correcting the error is a goal. The project evaluated the soil properties using in situ measurements and evaluate the soil properties. Detailed laboratory testing was performed for intermediate and fine-grained soils, and the results were examined in conjunction with the in situ test data and the associated site characterization data.

Sound recommendations can be developed from the project regarding liquefaction and the risks associated with it, such as ground deformation. Ground improvement methods like solidification, densification, and stone columns are confirmed as measures to deal with liquefaction. The project will aid understanding of the phenomenon of liquefaction.

3. Methodology

The project involves laboratory studies and analysis of intermediate soil together with field investigations to complement the research. Suspension logging, down-hole and surface-wave methods will be used, as well. These methods have the potential of addressing the aim of the project to explore the limitations of current methods. Moreover, this approach will aid in the estimation of the cyclic strengths and in situ static.

Another approach is through the study of the sample disturbance involving the behaviour of intermediate soil. To this effect, undisturbed block samples will be tested to complement the tube sampling. The testing will include investigation of intact soil for the effect of liquefaction. The parameters will be studied in situ.

The other approach in this project is evaluating the liquefaction potential of fine-grained and intermediate soil through the cycle behaviour and engineering procedures. Elaborate laboratory testing will be performed on sample intermediate and fine-grained soil and the results will be examined in conjunction with data from the complementary in situ test. The study analyses susceptibility of superficial deposits as it relates to texture, groundwater, age, depositional environment and sediment density.

Significance

This study has the potential of improving understanding of liquefaction and its effects, closing the knowledge gap that exists between specialists. Better understanding of the process can avoid the risk of potential damage associated with it. The project will be an information tool for scholars and practitioners in the construction industry.

Effect of soil–structure interaction on seismic performance-based design of concrete structures

1. My reasons and purposes for undertaking this project

When simulating an earthquake, the structure should not only be tested using records registering in the free field of soil. The dynamic response of a structure during an earthquake depends on the type of soil foundation. A realistic estimate of the effect of an earthquake on a structure cannot be made without this. Soil type, soil layer and changes in the depth of the layer are factors affecting the seismic behaviour of structures that have been considered in the analysis of structures. It can be said that soil-structure interaction produces behaviour that is closer to actual behaviour. After considering a soft soil substructure, structures assumed to have a rigid connection to the soil will show softer behaviour. Soil damping will increase all the damping of the system, but further review of the factors affecting the performance of a structure should be done.

The shift of functional design has been from the force method to design. After structural analysis and estimation of internal forces of members and deformation caused by gravity loads and lateral loads of an earthquake, the performance of structural components will be examined according to accepted criteria. In original and non-original members controlled by deformation, non-linear deformation analysis is beyond capacity. For this purpose, member deformation capacity should meet the proposed regulations by considering all simultaneous effects to a member.

To define the performance of a specified structure, it is necessary to identify the acceptable extent of damage of the earthquake. ATC40 and, FEMA 273 define three levels of structural performance as follows:

* Immediate occupancy: Structural damage after an earthquake is negligible and the vertical and lateral load-bearing structural systems maintain almost all properties existing before the earthquake.
* Life safety: Significant damage occurs to the structure but there is still a safety margin before considering the structure unstable. Structural and non-structural members will not fall.
* Structural stability or collapse prevention: Structural damage has reached the point at which the structures have not yet reached the stage of complete collapse and retain vertical stability.

The interaction of soil and foundation is the most important parameter influencing the level of expected performance of structures. The soil type and the substrate and the type of foundation of the substructure and the interaction between them causes a change in shift of the structures without interaction. A change in displacement can be expected to change the operating conditions of the original members and the overall performance of the structures.

2. My research project

In this study, the effect of soil-structure interaction on the performance of a structure will be evaluated according to performance-based design of concrete structures. The main objective of this study is to evaluate the effect of soil-

structure interaction on the expected performance of structures and detect possible changes in the level of performance of concrete structures with regard to soil-structure interaction.

To consider the interaction of soil and structures, the conical model will be used as a substructure method. In the conical model, the soil under the foundation is modelled as a divergent cone and displacement in the soil is applied through the massless and rigid foundation. According to type of displacement of soil, the conical model uses the rotational springs model to model the rotational movement, including circular and torsional motion. The transitional springs will be modelled in order to model vertical and horizontal displacement.

The level of expected performance for structures is based on FEMA 356. In order to consider the effect of foundation type on the structure, three different foundations will be considered:

1. A structure with a solid foundation;
2. A structure with a shallow foundation for soil of average quality;
3. A structure having a foundation with piles for loose soil.

Structural concrete structures examined in this study will be from the middle and upper classes. The system assumed for lateral structures moment frame system will be an average double bending frame with shear walls. This project will evaluate the influence the classes and lateral systems on the performance of structures.

3. Research Aims

1. To study the level of performance of the concrete structures considering soil-structure interaction;
2. To study the effect of the fundament on foundation interaction with the soil and its effect on structural performance;
3. To study the effect of soil-structure interaction for different levels of earthquake according to the levels of the structures.

4. Questions for research may include the following:

* Will soil-structure interaction negatively affect performance?
* Will soil-structure interaction have a greater effect on the performance of the main components of structures or on non-original members?
* Will the class and lateral system effect the level structural performance?

5. Methodology

There are two methods for evaluating the dynamic response of structures with regard to soil-structure interaction. In the first method, the free-field soil record in the soil is corrected and then the structure is analyzed under the modified record. In the second method, the soil is considered along with the structure. In this method, the structure and soil are used in a model that considers the effect of soil.

Methods that use free-field motion can be divided into direct and substructure methods. In the direct method, the soil and structure are modelled together and analysis is done in one step. Soil is often modelled by using solid finite elements and the structure using beam finite elements. The boundary of interaction is nearest to the contact area of the environment and structures. In this case, the stiffness of the soil around the structure is considered part of the soil. Because the theory of superposition of forces is not required, nonlinear analysis can be used.

In the substructure method (indirect method), the interaction boundary is in contact with the environment and structures. This border should be very accurate and indicates the soil stiffness of structures and the semi-infinite environment condition for the direction of wave propagation. The soil and structure are independently modelled and then the entire model is analyzed. In order to model the soil, springs and dampers are used that have properties that are dependent on excitation frequency.

This study takes into account soil-structure interaction using a cone model as a structural method. In the cone model, the soil under the foundation is modelled as a divergent cone and displacement of soil is applied throughout the massless and rigid fundament. Due to the relocation of soil, the cone model will be modelled using rotational springs to model rotational displacement that includes a cradle circular motion. The torsional and transitional springs will be modelled by considering the vertical and horizontal displacement.

In this project, tall concrete buildings having 10, 15 and 20-story plans will be modelled in OpenSees nonlinear software. For each of these structures, two types of bending system will be modelled (lateral bending frame and shear walls with a bending frame) for three types of fundament.

Non-Linear analysis of the stress–strain behaviour of unsaturated soil in response to earthquakes

1. My reasons and the purpose of undertaking this project

The climate of an area imposes specific environmental conditions on it. One of the most influential circumstances in a region is its soil moisture content. Any changes in soil moisture status will effect soil conditions. When the soil is not quite saturated or is dry, these soil conditions are commonly known as “partially saturated” and “unsaturated”. Almost 40% of the natural surface soil globally is unsaturated. The soil in the vicinity of the surface layers are more influenced by climatic, physical and environmental factors and their water content will be more variable.

One important mechanical and physical property of soil and aggregate dependence is the level of stress and strain. Determination of the basic relationship for expression of stress-strain in soil is difficult and prediction of the behaviour of all features in a model is practically impossible. Analysis and determination of the distribution of stress and strain in soil in geotechnical structures has traditionally been based on Hooke's law of elastic linear behaviour. The introduction of nonlinear elastic models was a new step forward for models in the prediction of the behaviour of soil. The stress-strain curve of unsaturated soil is much more complex and varied than for saturated soil and must be described properly by basic models in relation to the conditions of unsaturated soil.

Environmental factors and the passage of time create a natural soil structure. Structure and soil texture play an important role in its geotechnical features. Another important parameter for determining the stress-strain behaviour of soil is soil type. The soil type and higher percentages on gradation curves indicate that certain substances can change the behaviour of soil. Dynamic parameters are essential to the analysis and design of geotechnical structures in nonlinear analysis under dynamic loading. It is essential to have sufficient information about the response and behaviour of unsaturated soils under loading to design and build safe and economic structures. Cyclic loading on the foundations can be caused by coastal waves, wind, operating machinery, wind turbines and earthquakes. The addition of cyclic loads increases the pore pressure in the soil. In sandy soil, if the magnitude and number of cycles of loading are high and the periods of the soil and earthquakes are close, the resulting pore pressure will be equal with effective stress between the soil particles and soil shear strength will decrease with the destruction of the interaction between sand grains. A decrease in soil strength and stiffness can cause damage in whole or in part of foundation and can create a substantial mass settlement of soil. Plastic strain is a major cause of high settlement foundations under cyclic loading.

Lack of consistency between the laboratory tension-strain charts (triaxle testing) and the results of the proposed models for saturated soils is a problem facing researchers. A change in the behaviour of soil caused by a change in the soil saturation parameters and dynamic loading are crucial issues in the design of geotechnical structures. The safety of these structures require accurate understanding of soil behaviour.

2. My research project

This study will design a simple model for saturated soil under elastic-plastic unsaturated soil conditions to determine the effects of dynamic loading from earthquakes on soil. The Barcelona theory will be used determine a model for the Bishop effective stress hypothesis (assuming constant residual strength) and borderline levels of critical loading. Changes in the normal consolidation soil line in the two-dimensional space of porosity in the soil confining pressure caused by the increase or decrease saturation of soil samples will be examined. For this purpose, models of behaviour set by numerical models will be applied on the normal samples. The results of saturated and unsaturated triaxle tests on soil samples under especially normal stresses and different suctions will be compared in dry weather and wet obtained by Alonso [3]. Using the results, effective stress parameter is obtained for the unsaturated soil condition and in conditions of constant suction, stress-strain curves in dry conditions compared with their wet states.

3. Research Aims

Determination of the equations governing the stress-strain behavior of unsaturated soil under earthquake loading
Check suction changes in unsaturated soil under seismic loading
Determine the effect of an earthquake on changes in effective stress during consolidation
Assess changes in saturation on the soil shear strength at different levels of loading

4. Questions for research may include the following:

* How do changes in soil saturation effect the soil stress-strain curve?
* What is the effect of dynamic loading of soil on soil pore water pressure, plastic strain and effective stress curves?
* What is the effect of dynamic loading on unsaturated soil shear stress of the soil sample?
* When will the soil suction-saturation curve shift to dynamic loading?

5. Methodology

The most important factors for modelling of elastic-plastic behaviour of saturated soil are:

* Changes in behaviour of soil occur according to the water saturation of the soil.
* The hydraulic behaviour of soil is dependent on factors such as suction, saturation, and porosity changes.
* Changes occur in the effective stress of soil under seismic dynamic loading.

The study will evaluate hydraulic hysteresis effect by composing a chart of unsaturated soil behaviour versus the percentage of soil saturation. This curve will be used to expand the classical relationship with water retention curves.

The Effect of Climate Change on the Biogeochemistry of Estuarine Soft Soils

1. Background

This project aims to focus on the biogeochemistry of estuaries in relation to the effect of climate change. Estuaries have known benefits such as trapping, filtering and recycling suspended particulate matter and other components that have the potential to pose great harm to human health through pathogenic viruses. The effects of climate change are likely to cause loss of on habitat in estuarine ecosystems. Therefore, soft soils are also expected to be impacted. This project uses analyses to demonstrate how various processes triggered by climate change may impact the biogeochemistry of estuarine soft soils. Considerations of climate change were used for analyses were those of increased sea surface temperature, rise in sea level, storm surge, rainfall and river flow. According to the Intergovernmental Panel on Climate Change (IPCC), global temperatures are likely to increase during the 21st century. For instance, the UK sea surface is expected to warm by up to 40 C by the end of the century. Global mean sea levels are also expected to rise to 74 cm, according to amount predictions of future carbon dioxide emissions. This paper aims to identify how such changes will impact the biogeochemistry of the estuarine soft soil.

2. Project Aim

This research aims to identify the present biogeochemistry of estuarine soft soils through design of a biogeochemistry based sampling program. It will measure soil texture, color, aggregation, bulk density, porosity, organic horizon mass and layer thickness, total C and nutrient concentrations (N, P, S), and many other parameters in a present soil sample. It will then compare this present state to previous information on the biogeochemistry of estuarine soft soil in an attempt to highlight changes that may have taken place. This will encourage identification of the effects of climate change on the evaluated soil. The different consequences of climate change to be considered include sea surface temperature, rise in sea level, storm surge, rainfall, and river flows. Results of the biogeochemistry sampling will be related to estuarine soft soil. Any limitations to the research will be explored according to the ideas derived from in situ study, as well as the data from previous surveys.

3. Methodology

This research will apply a program for biogeochemistry sampling. It will feature measurements that will enable evaluations of biogeochemical changes in estuarine soft soil. Measurements will focus on the drivers of biogeochemical cycles including soil physical and chemical properties, soil temperature, and soil moisture content. Analysis for soil texture, color, aggregation, bulk density, porosity, organic horizon mass and layer thickness, total C and nutrient concentrations (N, P, S), and many others will be made. Such attributes impact the distribution of resources in the soil matrix, such as air space and the development of hydrological flow paths. There will also be a collection of previous surveys conducted on estuarine soil samples to support identification of changes that may have taken place over past years.

4. Project Significance

This research has the potential to create awareness on the impacts that climate change may have on estuarine soft soil. It has the capability of closing the gap in knowledge that exists in the field. By developing a clear understanding of the effects of climate change on biogeochemistry of estuarine soft soil, specialists will be better placed to make recommendations to the public. For example, the research may be applied to suggest ways to reduce the impacts of climate change on the environment. Specialists will have access to explanations on how such effects are indirectly impacting on human health. Therefore, this project will serve as a tool for reference, especially for scholars who specialize in the field.

Non–Linear Analysis of Soil–Pile–Structure Interaction on Structures with Piled Raft Foundation

Background

Deep foundations are conventionally designed by implementing large safety coefficients for piles. The piles in a pile foundation are positioned in a way they bear the whole load exerted by the structure. Although the pile foundation cap, which is usually in form of raft foundation, is in close contact with the soil, the loading share of the cap is usually neglected in comparison with the total loading capacity. In recent decades, increasing the knowledge about these foundations, using pile foundation and connecting it to the raft foundation, so that it would fully contact the soil, have significantly resulted in cost effectiveness of the project and increased efficiency of the foundation [1]. In this type of foundations, the raft also participates in structural load-bearing. This type of foundations are called "Piled Raft Foundation".

Composite piled raft foundations are composite structures consisting of pile, raft, and underlying soil. Given this scheme, piles are generally responsible for controlling the subsidence, rather than bearing the whole load. This type of foundations have positive effects such as reduced uplifting caused to excavation, reduced subsidence, relative subsidence, and slipping and, in case of high load eccentricity, they make actions and reactions concentrated and reduce the bending moment of the raft component. Application of piled raft foundation is appropriate when the raft foundation has sufficient loading capacity, but the subsidence or relative subsidence exceeds allowable values. In contrast, in some cases, for example when the soil profile near the surface consists of soft clay, or soft compressive layers are in relatively shallow depths, etc., using piled raft foundation might be undesirable [2]. However, using piled raft foundations has some disadvantages in terms of analysis and design as the soil-structure interaction must be considered in it, which is very complicated. For tall buildings, due to the relatively large load exerted on the foundation, varied length piled raft system is used. In order to control differential subsidence in this method, the tallest piles are usually placed in the middle, while short piles are placed on the edges.

Aims

The purpose of this study is to investigate soil-pile-structure interaction in changing dynamic properties of the structure, as well as the performance of pile foundation in a piled raft foundation system. The changes in the amount of energy dissipation of the structures and foundation loading capacity, taking into account the interactions, are studied.

Research Methodology

The behavior of a composite piled raft foundation is so complex that it cannot be dealt with by analytical methods. But finite element method is very comprehensive and adaptive to study complex problems. In order to investigate soil-pile-structure interaction, a number of tall structures with different number of floors and different lateral loading systems were modeled in PLAXIS 2D finite element software. One of the important and effective parameters in this analysis is the type of soil in the model considered. In this regard, it has been tried to select three soil samples with various and common properties. Researches of Wulandari at al. (2015) [3] are used in this section. Another important parameter in the modeling is the depth and number of piles modeled. In this regard, efforts have been made to examine the effect of these two parameters on interaction behavior of the system by changing them within reasonable ranges.

Significance

Deep soft soil deposits usually appear during construction in coastal areas. In order to mobilize the topsoil to sufficiently participate in the piled raft foundation interaction, the piled raft foundation scheme has been extended to a new type of foundation called composite piled raft foundation. This type of foundation is an economic approach for foundation designers in coastal areas. In composite piled raft foundation systems, short piles made of elastic materials, such as soil-cement columns or sand-gravel columns, are used to improve loading capacity of the lower surface natural soil, while long piles made of relatively rigid materials, such as reinforced concrete, are embedded in deep layer of hard clay or other load-bearing layers to reduce subsidence. Sand-gravel pads are also implemented between the raft component and piles aiming to re-distribute and adjust piles tension with the subsoil [4].

The load capacity of piled raft foundations depends on the interactions prevailing in them.

Pile-Soil-Interaction

Pile-Pile-Interaction

Soil-Raft-Interaction

Pile-Raft-Interaction